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An investigation of effect of microwave energy on electrostatic separation of colemanite and ulexite

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ABSTRACT

In this study, an effect of microwave treatment on electrostatic separation of boron minerals namely colemanite and ulexite, obtained from Eti Mines Inc.'s Bigadic Mines in Turkey, was studied in order to determine the changes of electrostatic properties. The X-ray diffraction analyses for the samples showed that colemanite structure was not affected by microwave heat treatment till 900 W power level; however ulexite structure was decomposed after 360 W power level. In addition, TG/DTA results showed that colemanite started to lose its crystal water content at 370.1 (260–427)°C, whereas ulexite lost its crystal water content at 621.9 (60–855) °C. The SEM pictures for the samples also confirmed that microwave treatment affects considerably the particle surfaces in a certain level. The electrostatic separation tests for pure colemanite and ulexite minerals of 1×0.5 mm size range at the 10 kV, 18 kV, 20 kV, and 22 kV applied voltages without heating and with heating at 65 °C showed that the colemanite mineral particles behaved as non-conductive up to 18 kV at room temperature and it kept its non-conductivity after heating it at 65 °C and 22 kV. On the other hand, ulexite minerals behaved as conducting at low voltage and room temperature, but it became non-conductive after heating at 65 °C by increasing voltages. These results clearly indicate that separation of these two hydrated borates from each other might be possible for recovery of boron minerals in the industry due to electrostatic properties difference of colemanite and ulexite by heat treatment.

1. Introduction

Colemanite ($Ca_2B_6O_{11}\cdot 5H_2O$) and ulexite ($NaCaB_5O_9\cdot 8H_2O$) are the most commercially important hydrated boron minerals beside tincal ($Na_2B_4O_7\cdot 10H_2O$) produced by Eti Mines Inc.'s several mines located in Western Anatolia of Turkey (Ozkan et al., 2008). Boron compounds are used in the manufacture of a variety of industrial products including advanced materials. World reserves of boron minerals are estimated to be 1241 Mt B_2O_3 and about 90% of the world's boron reserves in the world are located in the United States of America and Turkey (Roskill, 2009).

Microwave is a form of electromagnetic energy which travels in high frequency waves from 0.001 to 1 m with corresponding frequencies ranging from 0.300 to 300 GHz (Xia and Pickles, 1997; Haque, 1999). The most commonly used frequencies for heating purposes are 0.915 and 2.450 GHz, which corresponds to wavelengths of 0.012–0.335 m, respectively (Bathen, 2003; Al-Harahsheh and Kingman, 2004). The heat transfer mechanism in microwave heating is different from conventional heating. Microwave energy transmits heat to center and surface of a material simultaneously, i.e. independence of thermal conductivity on heating rate is overcome and time required to heat materials can be shortened (Pickles, 2004).

Microwave applications as a pretreatment technique in industry, particularly in mineral processing, have been used extensively (Clark et al., 2000; Jones et al., 2002). An advantage of microwave pretreatment is a decrease of heating time in some processes, and hence the low energy consumptions. Especially, the effects of microwave applications on drying, dehydration, and grindability are important, and research studies on these aspects have been studied by various researchers (Walkiewicz et al., 1991; Kingman et al., 2000).

Various applications of microwave heating have been proposed for the processing of minerals (Thostenson and Chu, 1999). One particular area is the reduction of grinding costs through a phenomenon known as thermally assisted comminution which is the heating and quenching of ores to reduce lattice strength, therefore reducing grinding costs. Conventional thermally assisted liberation of minerals requires large heat inputs and the overall energy balance is unfavourable (Kingman and Rowson, 1998; Kingman et al., 2000).

Although there are several studies focused on applications of microwave energy within copper, lead and zinc minerals and some coal types, there is a few studies for microwave treatment on boron minerals (Vorster et al., 2001).

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Table 1
Chemical analyses of the minerals.

Minerals	B_2O_3 (%)	CaO (%)	Na_2O (%)	MgO (%)	SiO_2 (%)	SO_4 (%)	SrO (%)	Al_2O_3 (%)	Fe_2O_3 (%)	As (ppm)	LOI (%)
Colemanite	49.17	26.71	0.25	1.27	2.95	0.26	0.09	0.08	0.012	3.030	19.01
Ulexite	42.98	13.80	3.20	0.46	1.78	0.20	0.74	0.05	0.010	33.33	35.90

The following studies showed that ulexite was illustrated as conductive at room temperature after electrostatic separation tests, however, it gained insulating (non-conducting) properties at 80 °C (Yasar, 1994). In the same research, colemanite was shown to have insulating properties at room temperature till temperatures up to 80 °C, however it was also stated in another study that both minerals had insulating and conducting properties if the crystal structures contained carbonaceous materials (Celik and Yasar, 1995a).

In this study, an effect of microwave treatment on electrostatic separation of colemanite and ulexite minerals was investigated in order to determine the changes of electrostatic properties of the minerals. The chemical and mineralogical analyses were also conducted to reveal the effects of microwave energy on the mineral surfaces.

2. Materials and methods

2.1. Materials

Pure colemanite and ulexite samples used in this study were obtained from the Eti Mines Inc.'s Bigadic Mines. The mineral surfaces were washed by tap water for removal of clayish minerals, and dried at room temperature (22 °C). Then, the minerals were crushed, and classified to particle size of 1 × 0.5 mm. A conventional laboratory type drying oven was used for removal of surface moisture. A kitchen type microwave oven with 2.450 GHz frequency was used for surface modifications by microwave energy at 360 W power with duration of 30 min before the electrostatic separation (Eskibalci, 2007).

The chemical analyses of the minerals were also performed at Eti Mines Inc.'s Bigadic Mines, and the results are presented in Table 1. The analyses of B_2O_3 and H_2O contents were conducted by volumetric techniques, and others were conducted by X-ray fluorescence equipment.

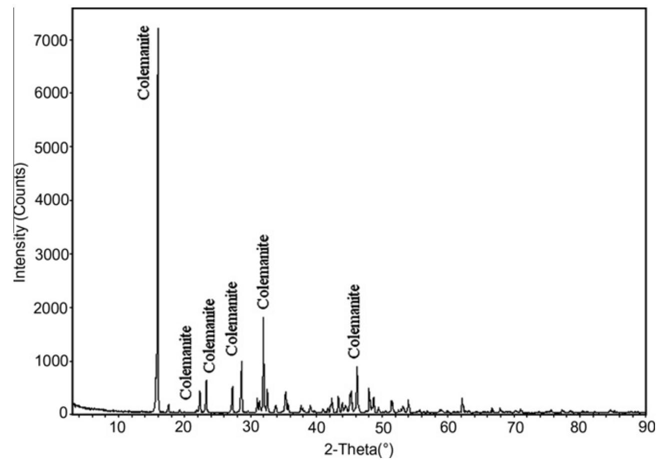

Fig. 1a. X-ray diffraction analyses of original colemanite sample.

The X-ray diffraction analyses were also performed to determine the mineralogical structure of original and microwave treated samples using Rigaku D. Max. 2200 PC XRD 200 Vac 3g 20 A/50 Hz apparatus. The results indicated that the peak of the XRD assays confirms the purity of the samples. X-ray diffraction analysis results of original and microwave treated colemanite and ulexite samples according to various power levels (180–900 W) are presented in Figs. 1a and b and 2a and b, respectively.

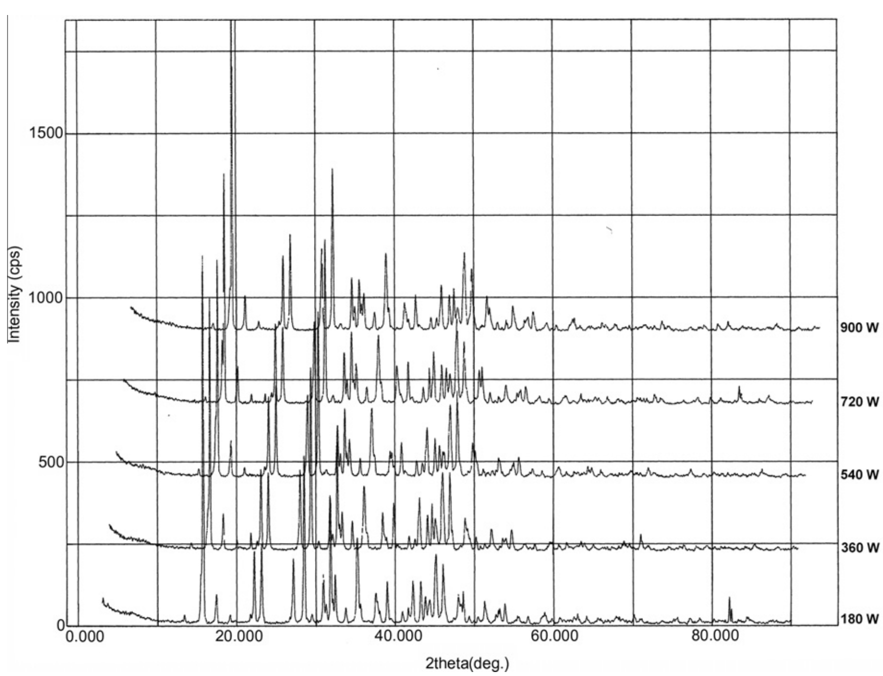

Fig. 1b. X-ray diffraction analyses of microwave treated colemanite sample.